UNITED STATES

NUCLEAR REGULATORY COMMISSION OFFICE
OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

August 1, 2005

INFORMATION NOTICE 2005-23: VIBRATION-INDUCED DEGRADATION OF BUTTERFLY VALVES

ADDRESSEES

All holders for operating licenses for nuclear power reactors except those who have permanently ceased operation and have certified that fuel has been permanently removed from the vessel.

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees to the degradation of butterfly valves supplied by Fisher Controls and other manufacturers. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

On February 10, 2005, Southern California Edison declared component cooling water (CCW) outlet isolation valve 2HV6500 for the Train B shutdown cooling (SDC) heat exchanger in Unit 2 at the San Onofre Nuclear Generating Station (SONGS) inoperable in response to an abnormal reduction in flow through the valve. Valve 2HV6500 is an 18-inch butterfly valve manufactured by Fisher Controls. The operability of the containment spray (CS) system at SONGS Unit 2 depends on the availability of the SDC heat exchanger. Therefore, the licensee started a manual shutdown of SONGS Unit 2 on February 14, 2005, to repair the valve.

The licensee disassembled the valve and found that it could not fully open as a result of losing two taper pins that connect the valve disc to the valve stem. During the original installation, the taper pins are impact-driven into holes in the valve disc and stem and are intended to be held in place by the interference fit. The licensee could not determine the exact cause of the loss of the taper pins during plant operation. As corrective action, the licensee installed new taper pins and staked the pins to the valve disc to make them more secure.

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Since 1993, five Fisher Controls 28-inch butterfly valves in the CCW systems of SONGS Units 2 and 3 have lost one of the taper pins used to connect the valve disc to the valve stem. The licensee has also found additional Fisher Controls butterfly valves with improperly seated taper pins during internal inspections.

The design of the Fisher Controls butterfly valves can allow leakage through the valve if a taper pin is lost. For example, SONGS experienced leakage rates of approximately 50 gallons per minute (gpm) through 28-inch Fisher Controls butterfly valves in the CCW system in 1998 and 2004. After disassembling the butterfly valves, the licensee identified the cause of the leakage as the loss of a single taper pin in each of the valves.

Taper pins that come loose from butterfly valves can be carried with the system fluid and interfere with the operation of other plant equipment. For example, one of the missing taper pins from 2HV6500 at SONGS Unit 2 became lodged in train “B” CCW pump manual discharge isolation valve 2HCV6509, which is normally locked open and closed only for maintenance purposes. After maintenance on the train “B” CCW pump, the licensee had difficulty opening 2HCV6509 because of the taper pin lodged in the valve.

The licensee plans to review all butterfly valves in safety-related applications where loss of valve function or leakage because of a missing taper pin cannot be tolerated. On the basis of the review, the licensee will determine which butterfly valves to inspect during the upcoming refueling outages at SONGS Units 2 and 3. As part of the valve inspections, the licensee will stake the taper pins in the butterfly valves to ensure the pins remain in place during plant operation.

DISCUSSION

Over the years, nuclear power plants have experienced vibration-induced degradation of plant equipment during operation at the original licensed power and under power uprate conditions. The NRC has issued several information notices on vibration-induced degradation of plant equipment. For example, the NRC issued Information Notice (IN) No. 83-70, “Vibration-Induced Valve Failures,” on October 25, 1983, to alert nuclear power plant licensees to valve failures and system inoperability as a result of normal operational vibration.

The degradation of Fisher Controls butterfly valves as a result of the loss of their taper pins at SONGS Units 2 and 3 is another example of vibration-induced degradation during plant operations. There have also been problems with the taper pins that connect the valve disc to the stem in butterfly valves supplied by other manufacturers. In 1989 Turkey Point Nuclear Plant, Unit 4, lost taper pins in a 36-inch intake cooling water head isolation butterfly valve manufactured by the Henry Pratt Company. In 2003 Davis-Besse Nuclear Power Station, Unit 1, lost taper pins in a 10-inch decay heat cooler butterfly valve with the brand name Valtek marketed by the Flowserve Corporation.

Depending on the valve design, the loss of a taper pin from a butterfly valve may result in significant leakage through the valve before interfering with valve operation. The size of the taper pin and fluid conditions can cause the leakage limits for the applicable plant system to be exceeded. In addition, leakage through a valve can be masked by another closed valve in the system until the second valve is opened.

Taper pins that come loose from butterfly valves can be carried with the system fluid and interfere with the operation of other plant equipment. The example of 2HCV6509 at SONGS Unit 2 had low safety significance because this valve is only used for maintenance at the plant.

Some nuclear power plants have experienced more severe vibration-induced degradation of equipment under power uprate conditions. For example, the NRC staff described vibrationinduced degradation of plant equipment during power uprate operation in IN 2002-26, Supplement 2, “Additional Flow-Induced Vibration Failures After a Recent Power Uprate” (January 9, 2004). Increased steam and feedwater flow during power uprate operation can increase vibration of plant equipment, including valves and valve actuators. The higher vibration levels can impact the appropriate inspection intervals for some plant components.

In summary, degradation of butterfly valves supplied by Fisher Controls and other manufacturers has occurred during plant operation as a result of the loss of taper pins used to connect the valve disc to stem. The degradation can involve leakage and affect valve operation. Taper pins lost from butterfly valves can also interfere with the operation of other plant components in fluid systems. The cause of the loss of valve taper pins is not known for certain, but operating experience suggests that the most likely cause is vibration-induced degradation. Staking the taper pins after their installation in the butterfly valves is one method of providing a more secure interference fit of the pins. The increased steam and feedwater flow during power uprate operation can accelerate vibration-induced degradation of plant equipment, including valves and valve actuators.

RELATED GENERIC COMMUNICATIONS

NRC Information Notice 83-70, "Vibration-Induced Valve Failures," October 25, 1983.

NRC Information Notice 2002-26, Supplement 2, "Additional Flow-Induced Vibration Failures After a Recent Power Uprate," January 9, 2004.

This information notice requires no specific action or written response. However, recipients are reminded that they are required by 10 CFR 50.65 to consider industry-wide operating experience (including information presented in NRC information notices) where practical, when setting goals and performing periodic evaluations.

CONTACT

Please direct any questions about this matter to the technical contact(s) listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

/D.C. Trimble for/

Patrick L. Hiland, Chief
Reactor Operations Branch

Division of Inspection Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Thomas G. Scarbrough, NRR Mark A. Sitek, Region IV

(301) 415-2794(949) 492-2641

E-mail: tgs@nrc.govE-mail: mas3@nrc.gov

Ronald V. Schmitt,
NRR (301) 415-4082
E-mail: rvs@nrc.gov

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UNITED STATES

NUCLEAR REGULATORY COMMISSION OFFICE
OF NUCLEAR REACTOR REGULATION
WASHINGTON, DC 20555-0001

November 20, 2006

NRC INFORMATION NOTICE 2006-26: FAILURE OF MAGNESIUM ROTORS IN MOTOR-OPERATED VALVE ACTUATORS

ADDRESSEES

All holders of operating licenses for nuclear power reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees of recent failures of motor-operated valve (MOV) actuators that were attributed to the oxidation and corrosion of the magnesium motor rotor fan blades and shorting ring resulting from exposure to high humidity and temperatures. This IN serves to reaffirm the necessity of adequate inspection and/or preventive maintenance on MOV actuators manufactured with magnesium rotors to ensure the safe operation of nuclear power facilities. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

A recent NRC staff review of MOV actuator failures at certain plants identified the following examples:

(302) Failure of a Main Feedwater Isolation Block Valve to operate automatically (Crystal River 3; October 28, 2005; Licensee Event Report (LER) 50-302/2005-004-00). The licensee attributed this failure to the corrosion and oxidation of the magnesium fan blades and shorting ring of the motor rotor as a result of exposure to high humidity and temperatures.

(303) Failure of the Residual Heat Removal (RHR) Cold Leg Injection Valve to open when placing RHR in operation for cooldown (Turkey Point 3; March 6, 2006;

LER 50-250/2006-003-00). The licensee attributed this failure to the corrosion and oxidation of the magnesium fan blades and shorting ring of the motor rotor as a result of exposure to high humidity and temperatures.

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(3) Failure of a Recirculation Pump Suction Valve to operate (Browns Ferry 3;

January 15, 2006; documented in the licensee's corrective action program). The licensee attributed this failure to the corrosion of the motor rotor fan blades and shorting ring.

BACKGROUND

Many safety- and non-safety-related MOVs utilize Limitorque actuators with Reliance motors or a similarly styled design by a different manufacturer. Based on torque requirements, aluminum and magnesium alloy cast-squirrel-cage rotors are utilized in MOV actuators. Valve actuators with a motor maximum torque of 40 foot-pounds force (54 Newton-meters) are typically aluminum, and magnesium actuators are used for applications requiring greater than 60 foot-pounds force (81

Newton-Meters).

The typical magnesium rotor is made of stacked, steel punched core plates with AM100A magnesium alloy (approximately 90% magnesium, 10% aluminum, 0.1% manganese) components—the conductor bars, end rings, and cooling fan blades—cast to complete the rotor. While magnesium provides higher torque through its higher resistivity, this relatively brittle cast alloy is susceptible to shrinkage cracking and gas porosity. Specifically, magnesium rotors are susceptible to three main failure mechanisms: galvanic corrosion, general corrosion, and thermally induced stress.

The first failure mechanism is galvanic corrosion. Following manufacture, the electrical potential difference between the magnesium and the steel core is 1.9 volts creating the conditions for galvanic corrosion, with the most vulnerable area being the interface between the steel core and the magnesium end ring. Most manufacturers alleviate this by protecting the magnesium end rings with a paint and/or lacquer coating. Though the rotor might be initially protected, even the smallest scratch or chip in this exterior coating will cause localized, accelerated corrosion in the form of magnesium hydroxide (MgOH) powder. The formation of MgOH powder leads to rotor cracks that add to the existing problems of shrinkage cracking, gas porosity, and MgOH volume difference. Motor overheating events (typically due to locked rotor conditions) accelerate this coating degradation. A propagating crack at the interface between the stacked core and the end ring causes a high resistance connection with the end ring, which in turn causes a high current density (due to current redistribution) on the opposite side of the rotor. This increased current density increases the temperature on that side of the rotor resulting in thermal stress. At the steel-magnesium interface, the higher temperature may melt the magnesium into small beads. These thermally-stressed rotor areas and the melted magnesium beads then provide new opportunities for coating degradation and cracking resulting in new areas of high resistance between the stacked core and end ring and new areas of the rotor with a higher current density. This cycle of events can then repeat around the rotor.

The second major failure mechanism affecting magnesium rotors is general corrosion. Most actuator motors for safety-related MOVs that are located in potentially harsh environments have T-drain pipe plugs to allow moisture to escape. These same plugs allow moisture to enter and condense inside the motor. This moisture leads to the formation of MgOH and magnesium oxide (MgO_2). The white MgOH powder can form a light haze on the inside of the motor without impacting its operation. However, MgOH and MgO_2 can form beads between core plates (from the magnesium conductor bars) and at the interface between the stacked core and the end ring causing high resistance points and the high current density phenomena stated above and even further cracking. The rate of general corrosion increases in a higher humidity operating environment.

The third major failure mechanism affecting magnesium rotors is thermally induced stress which reveals itself in different ways. First, because galvanic corrosion is thermally catalyzed, the corrosion rate increases with temperature, with a significant increase in the corrosion rate occurring at temperatures above approximately 93 °C (200 °F). The rate of galvanic corrosion increases when the motor is located in a higher temperature environment, as well as during general motor high-current conditions and/or within the high current density regions mentioned earlier. Secondly, magnesium has twice the thermal expansion coefficient of steel. This produces uneven axial and radial forces across the rotor causing further cracks in the magnesium and its paint and/or lacquer coating. Finally, many rotors experience significantly higher temperatures because their thermal overloads are set higher than the recommended 10 to 15 seconds for locked rotor current conditions (in order to ensure safety-related function as given in NRC Regulatory Guide 1.106, Revision 1, "Thermal Overload Protection for Electric Motors on Motor-Operated Valves"). For example, some rotors reach 700 °F (371 °C) in 15 seconds, and temperatures of 700 °F to 850 °F (371 °C to 454 °C) cause a significant loss of magnesium yield strength.

Various laboratory tests have been conducted to better understand magnesium rotors. General Electric (GE) tested-to-failure 3 motors in varying aged and environmental conditions, with the most limiting failure being a new motor which failed after 43 days in a high temperature environment under a maximum temperature of 223 °F (106 °C). The Institute of Electrical and Electronics Engineers (IEEE) inspected 14 magnesium rotors and discovered 5 showing varying levels of degradation. Finally, IEEE reviewed plant motor failure rates and found magnesium rotors failing at three times the rate of aluminum rotors.

The following documents address similar MOV failures with related technical details:

! NRC Information Notice 86-02, "Failure of Valve Operator Motor during Environmental Qualification Testing," January 6, 1986: this IN reported on the results of the previously discussed GE laboratory test on three motors in response to issues at the River Bend and Nine Mile Point 2 nuclear power stations. In addition to the technical details stated earlier, the NRC within this IN suggested that licensees review the qualification of these motors in their Design Basis Event applications.

! NUREG/CR-5404, ORNL-6566/V1, "Auxiliary Feed Water Aging Study," July 1993:

while this report is extensive and covers many wide-ranging aspects, Section 4.5 (Alternate Methods of Valve Actuator Motor Testing) reviews two methods for the preventive maintenance of magnesium rotors.

! NUREG/CR-6205, ORNL-6796, "Valve Actuator Motor Degradation," December 1994:

this NUREG provides a detailed review of the technical phenomena citing all of the failure mechanisms with insights from the GE test and the IEEE report.

! IEEE Transactions on Energy Conversion, Vol. 3, No. 1, "An Investigation of Magnesium Rotors in Motor Operated Valve Actuators," March 1988: this IEEE report provides a detailed, technical analysis of the failure mechanisms and material impact of magnesium rotors. This analysis includes the review of various laboratory tests and licensee database reviews. This report includes a detailed inspection procedure for user guidance.

The IEEE report, NUREG/CR-5404, Crystal River LER 50-302/2005-004-00, Turkey Point LER 50-250/2006-003-00, and the operating experience from Browns Ferry provide some specific methods for preventive maintenance:

1. The IEEE report and the LER's from Crystal River and Turkey Point provide detailed inspection procedures with acceptance criteria. They specifically discussed boroscopic inspections of MOV actuators through the T-drain pipe as a preventive maintenance method.

2. The Crystal River LER also provides detail on performing electrical Polarization Index inspections from measurements of the motor winding insulation resistance.

3. NUREG/CR-5404 reviews motor current signature analysis as a method for revealing broken or distorted rotor bars.

4. The IEEE report reviews ideal thermal overload setpoints in order to avoid the thermally induced stresses discussed earlier but also proposes graduated inspection criteria if these setpoints are not met.

5. Operating experience from Browns Ferry describes their consideration of duty cycle limitations to ensure the motors are not actuated without a proper cooldown interval in order to avoid or not exacerbate thermally induced stresses.

DISCUSSION

Recent failures of MOV actuators as a result of galvanic corrosion, general corrosion, and/or thermally induced stress highlight the particular vulnerabilities of motor actuators with magnesium rotors, particularly when the motor is located in a high humidity and/or high temperature environment. These MOV failures illustrate the necessity of adequate inspection and/or preventive maintenance on actuators manufactured with magnesium rotors.

CONTACTS

This information notice requires no specific action or written response. Please direct any questions about this matter to the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation project manager.

/RA by Theodore Quay for/

Michael J. Case, Director

Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Technical Contacts: James Polickoski, RII
803-345-5683 E-mail: jtp@nrc.gov

Scott Stewart, RII
305-245-7669 E-mail: jss1@nrc.gov

Tom Morrissey, RII
352-795-7677 E-mail: txm1@nrc.gov

Robert Monk, RII
256-729-6196 E-mail: rlm2@nrc.gov

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UNITED STATES

NUCLEAR REGULATORY COMMISSION OFFICE
OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

December 14, 2006

INFORMATION NOTICE 2006-29: POTENTIAL COMMON CAUSE FAILURE OF MOTOR-OPERATED VALVES AS A RESULT OF STEM NUT WEAR

ADDRESSEES

All holders of operating licenses for nuclear power reactors except those who have permanently ceased operation and have certified that fuel has been permanently removed from the vessel.

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to alert addressees of potential common cause failure of motor-operated valves (MOVs) at nuclear power plants as a result of stem nut wear. The agency expects that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, the suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

On March 27, 2006, during the spring refueling outage for the Susquehanna Nuclear Power Plant, Unit 1, the suppression pool suction valve for the “D” residual heat removal (RHR) pump failed to close during system functional testing. On April 6, 2006, the suppression pool suction valve for the “C” RHR pump failed to stroke during system alignment. The licensee identified the cause of these MOV failures to be excessive wear of the internal threads of the stem nut that converts the rotational motion of the motor actuator to the lateral motion of the stem to open and close the valve.

In the MOV Preventive Maintenance (PM) program at Susquehanna, the licensee had relied on the observation of stem nut thread shavings below the actuator to identify stem nut wear and the need for stem nut inspection. The licensee had not directly inspected the stem nuts for the two failed MOVs for 20 years because no stem nut thread shavings had been found below the actuator. The licensee did not have a periodic overhaul program for safety-related MOVs, nor procedures to review stem nut thread clearance when conducting diagnostic testing of safety-related MOVs.

In response to these MOV failures, the licensee evaluated diagnostic traces of rising stem MOVs at Susquehanna, Units 1 and 2 that were within the scope of Generic Letter 89-10, “Safety-Related Motor-Operated Valve Testing and Surveillance.” The licensee studied the time span required for the rotating stem nut to take-up the clearance between the valve stem

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threads and the stem nut threads to assist in identifying potential stem nut wear. The licensee evaluated previous diagnostic traces to determine changes in thread clearance to estimate the stem nut wear rate and to determine whether sufficient thread would remain through the next operating cycle. Based on this information, the licensee inspected 31 safety-related MOVs at Susquehanna and replaced the stem nuts in 18 MOVs with wear exceeding 50% of the original thread thickness. The licensee plans to conduct additional MOV stem nut inspections in the future.

The RHR suppression pool suction valves at Susquehanna, Unit 1 are normally open and do not automatically change position to perform their safety function of allowing emergency core cooling water to be taken from the suppression pool. These valves also serve a containment isolation function in that they would be remotely closed if there was a break in the RHR system. The RHR suppression pool suction valves are interlocked with the RHR shutdown cooling suction valves to prevent these valves from being open at the same time and inadvertently draining the reactor vessel. Therefore, the failure of the RHR suppression pool suction valves might have impacted the emergency core cooling function of the RHR system, or affected the primary containment isolation function, depending on valve position at the time of failure. At the time of the event, primary containment integrity was not required. With the plant shut down for refueling, the safety significance of having two inoperable RHR suppression pool suction valves was considered low. Although the RHR pumps associated with the failed valves were not being relied upon to fulfill emergency injection requirements, valve failures associated with systems being relied upon for shutdown cooling or emergency core cooling (either shutdown or at power) might have either prevented or unexpectedly altered system function, thus, complicating operator actions and necessitating further response.

The licensee submitted Licensee Event Report (LER) 50-387/2006-003-00 on July 26, 2006, in response to the MOV stem nut failures at Susquehanna (see Agencywide Documents Access and Management System Accession No. ML062190207). In the LER, the licensee listed the following as root causes for the event: (1) valve stem visual inspections for evidence of stem nut thread wear were an ineffective means for monitoring long-term stem nut thread wear;

(2) routine PM activities for periodically inspecting stem nuts did not exist; and (3) procedural guidance for inspection and acceptance of stem nut thread wear was inadequate. The licensee reported that immediate corrective actions had been completed to evaluate safety-related MOVs at Susquehanna using previous diagnostic indications of stem nut thread wear and inspection of selected stem nuts to assess stem nut condition. Additional long-term corrective actions planned at Susquehanna include:

(3) performing additional MOV inspections and replacing stem nuts, when needed;

(4) revising the current 2-year PM activity bases, and to clarify the intent and limitations of stem inspections in response to the ineffectiveness of visual inspections to detect long-term stem nut wear;

(5) developing a new PM activity that periodically inspects selected MOV stem nuts;

(6) establishing a methodology and acceptance criteria for measurement of stem nut wear;

(5) incorporating detailed instructions for performing stem nut inspections into existing procedures;

(6) preparing procedural direction for monitoring and trending stem nut wear using MOV diagnostic data; and

(7) modifying stem lubrication PM activities to include valve stroking.

DISCUSSION

In an MOV, the stem nut converts the rotational motion of the drive sleeve in the motor actuator to the lateral motion of the stem to open and close the valve. Stem nut failure can prevent the operation of the MOV from either the motor actuator or manual handwheel. Stem nut failure can also cause valve position for the MOV to be incorrectly displayed in the control room. The failure of a stem nut for an individual MOV can interfere with the operation of other plant equipment when its valve position signal is supplied to interlock logic systems. Further, if the stem nut threads are destroyed, a valve could potentially drift open or closed should the valve packing be unable to hold the valve stem in position.

The stem nut of an MOV is typically made of bronze material. Over a period of time and use, the stem nut will undergo wear when rotating to move the steel valve stem to open or close the valve. Stem nut wear can be influenced by several factors, including the following: (1) stem nut material; (2) normal operating loads and maximum loads; (3) stem nut rotations during a valve stroke; (4) number and frequency of valve strokes; (5) stem nut manufacture and threaded length; (6) stem and stem nut fit; (7) valve stem thread condition; and (8) stem lubricant, lubrication method and frequency, and environmental conditions for the lubricant.

The unexpected failures and significant degradation of stem nuts in MOVs at Susquehanna emphasizes the importance of PM activities in identifying MOV stem nut wear in a timely manner. For example, the absence of significant changes in diagnostic performance for monitored MOV parameters (such as stem factor, thrust, or torque), or stem nut thread shavings below the actuator, might not be sufficient to confirm that the stem nut remains in good condition. Additional PM activities, such as periodic overhaul of safety-related MOVs or evaluation of MOV diagnostic test data for stem nut thread clearance, might be needed to identify stem nut wear. Further, it is important for the PM program to ensure that new lubricant is applied to the stem nut area, such as by stroking the valve, when lubricating safety-related MOV valve stems.

Excessive stem nut wear represents a potential common cause failure mode that could impact multiple MOVs at nuclear power plants. It is typically a long-term issue that is addressed as part of PM programs at nuclear power plants. Industry guidance includes stem nut inspection as part of MOV technical repair guidelines. Vendors of MOV diagnostic equipment include stem nut thread take-up clearance as a specific parameter for monitoring stem nut wear. Appropriate PM activities, such as those to be implemented at Susquehanna, can assist in identifying significant stem nut wear prior to MOV failure.

CONTACTS

This information notice requires no specific action or written response. Please direct any questions about this matter to the technical contacts listed below.

/RA/

Michael J. Case, Director

Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Technical contacts: Thomas G. Scarbrough, NRR James M. Trapp, Region I

(301) 415-2794 (610) 337-5186

E-mail: TGS@nrc.gov E-mail: JMT1@nrc.gov

Alan J. Blamey, Region I (570) 542-2134 E-mail:

AJB3@nrc.gov Terry A. Beltz, NRR (301) 415-3049 E-mail: TAB3@nrc.gov

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